Wind Plant Performance Prediction (WP3) Benchmark Introduction

UBS Webinar Series
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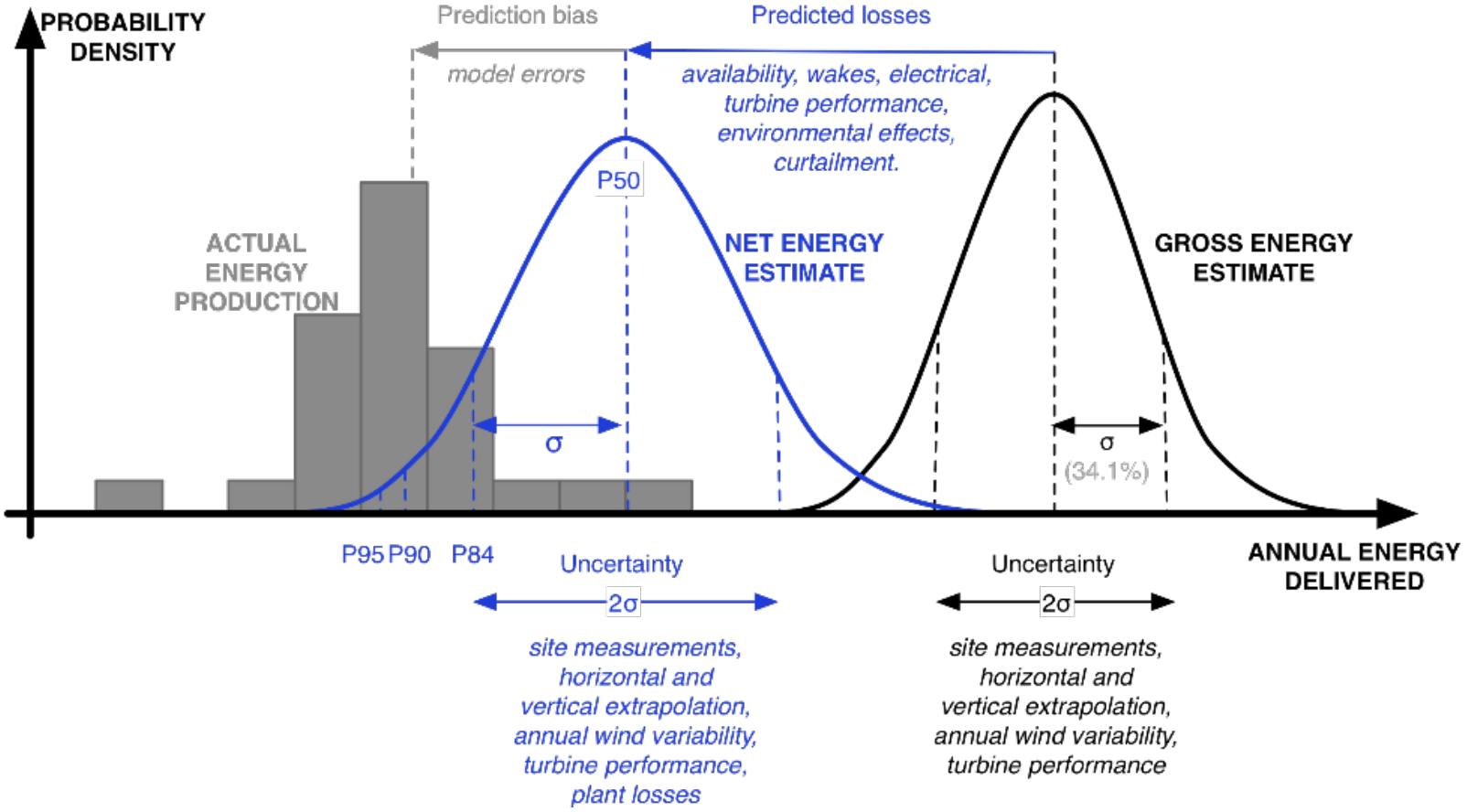
NREL/PR-5000-74347

Project Overview



Source: A. Clifton (2016)

WP3 Benchmark Initiative

The problem:

1. Increasing market pressures on wind
2. Real uncertainty is out of sync with industry expectations
3. Estimated project returns may be below project targets

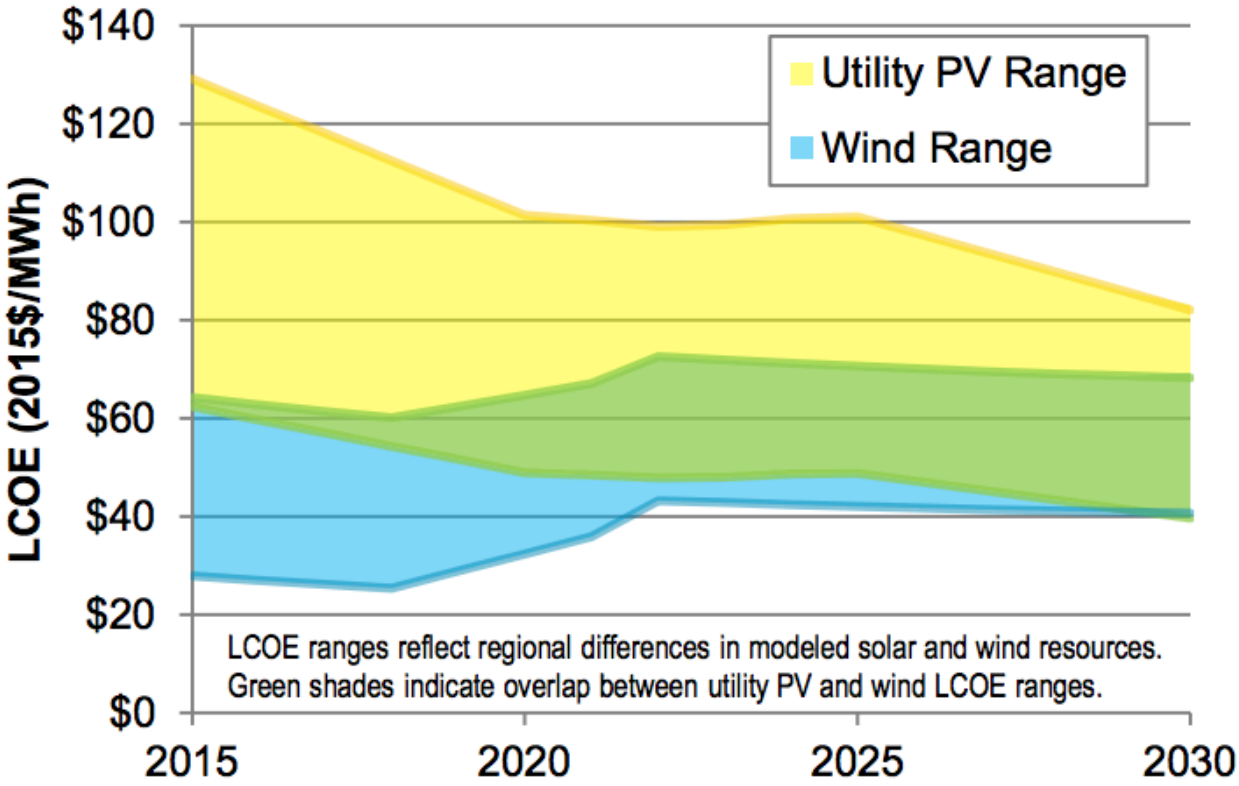
The solution:

Work together to improve

Put valuable data in the hands of the smartest people

Wind Market Pressures

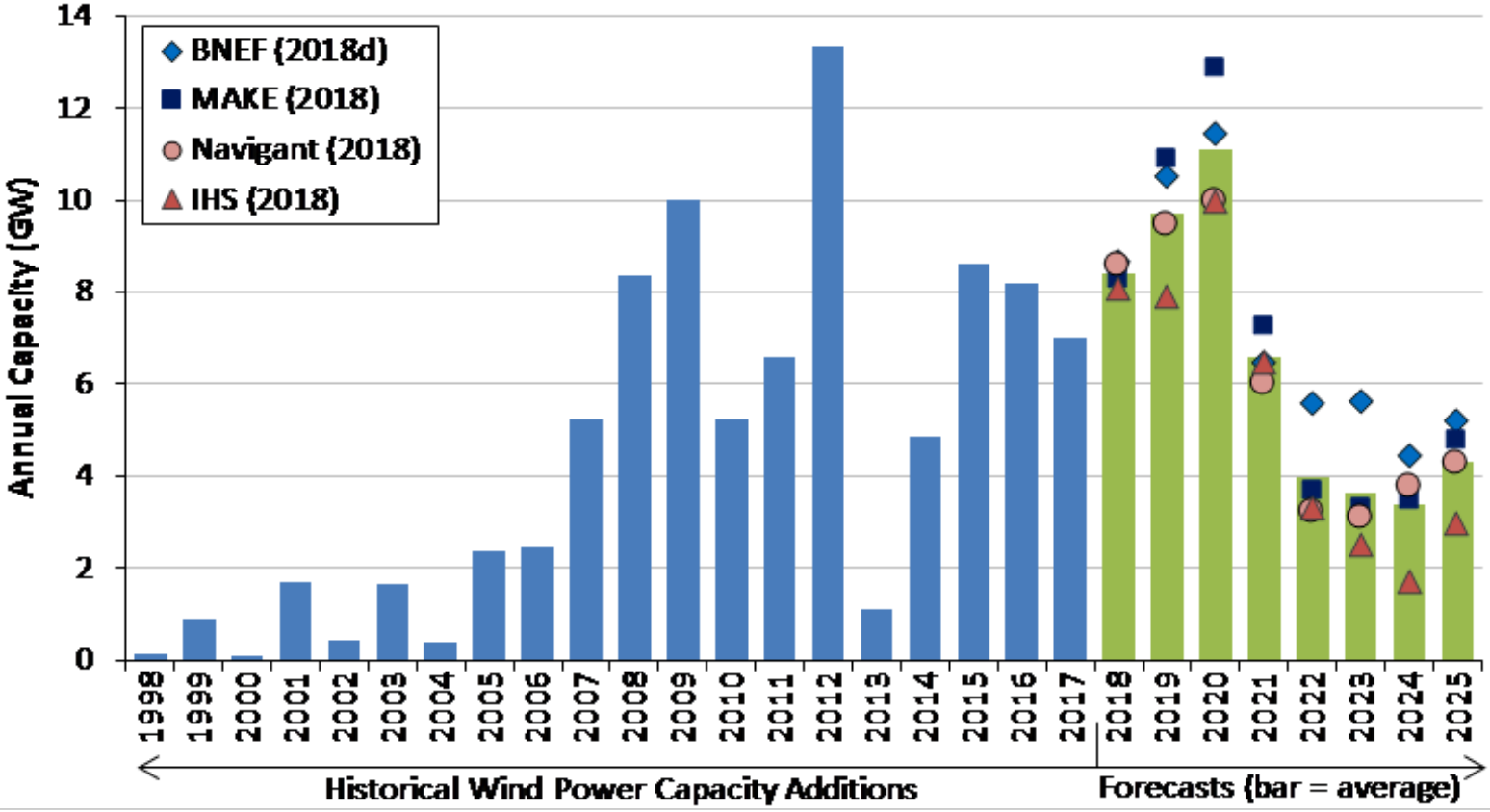
Claim #1: Market pressures



Source: T. Mai (2016)

Production Tax Credit Expiration

Claim #1: Market pressures



Source: LBL Wind Market Report

Prediction Validation

Anecdotally…

If the energy estimate is 3% too high, the owners have lost all their profit…

1% change in energy yield is equivalent to ~$20/kW in the turbine price, or ~$4M NPV.

Developers battle consultants to get back 0.5% in losses

Turbine location optimizations run for days to find the most ideal location for every turbine

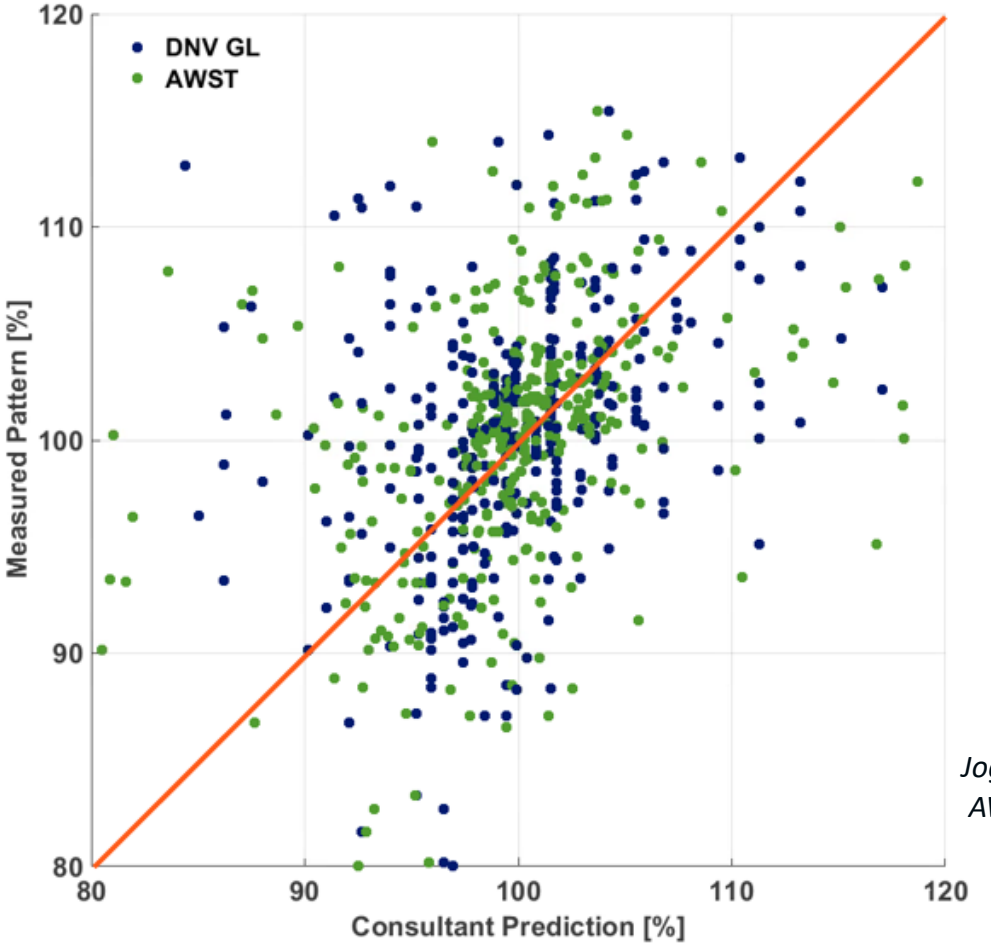
It takes 100–200 hours for a consultant to complete an energy assessment

And yet…

Claim #2: Real uncertainty is out of sync with industry requirements

Prediction Validation

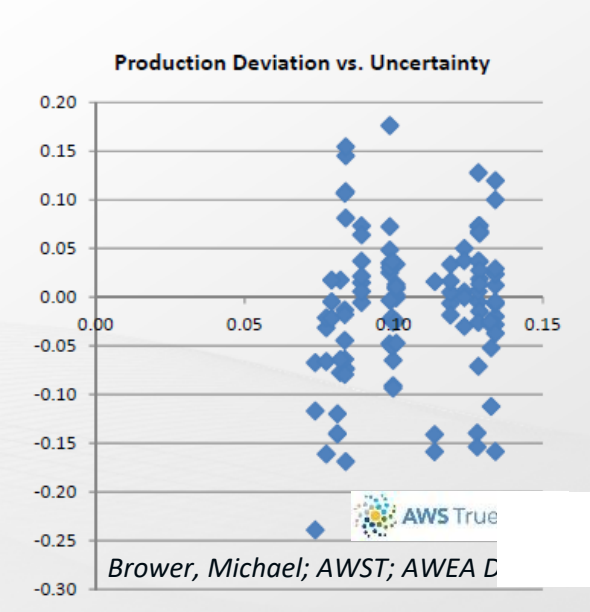
How good are we at predicting variability inside a site?



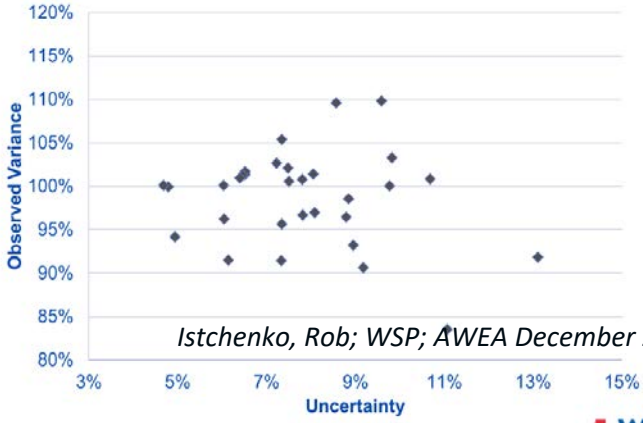
Jog, Cory; EDF RE;
AWEA September 2015

Prediction Validation

How good are we at estimating project uncertainty?

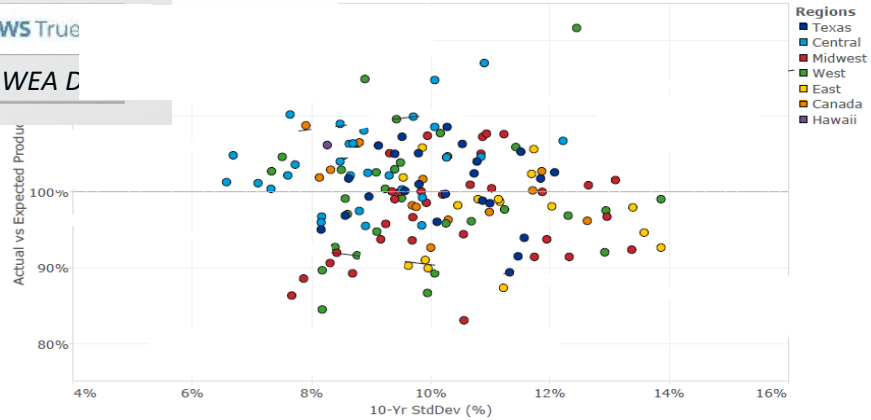


Brower, Michael; AWST; AWEA D



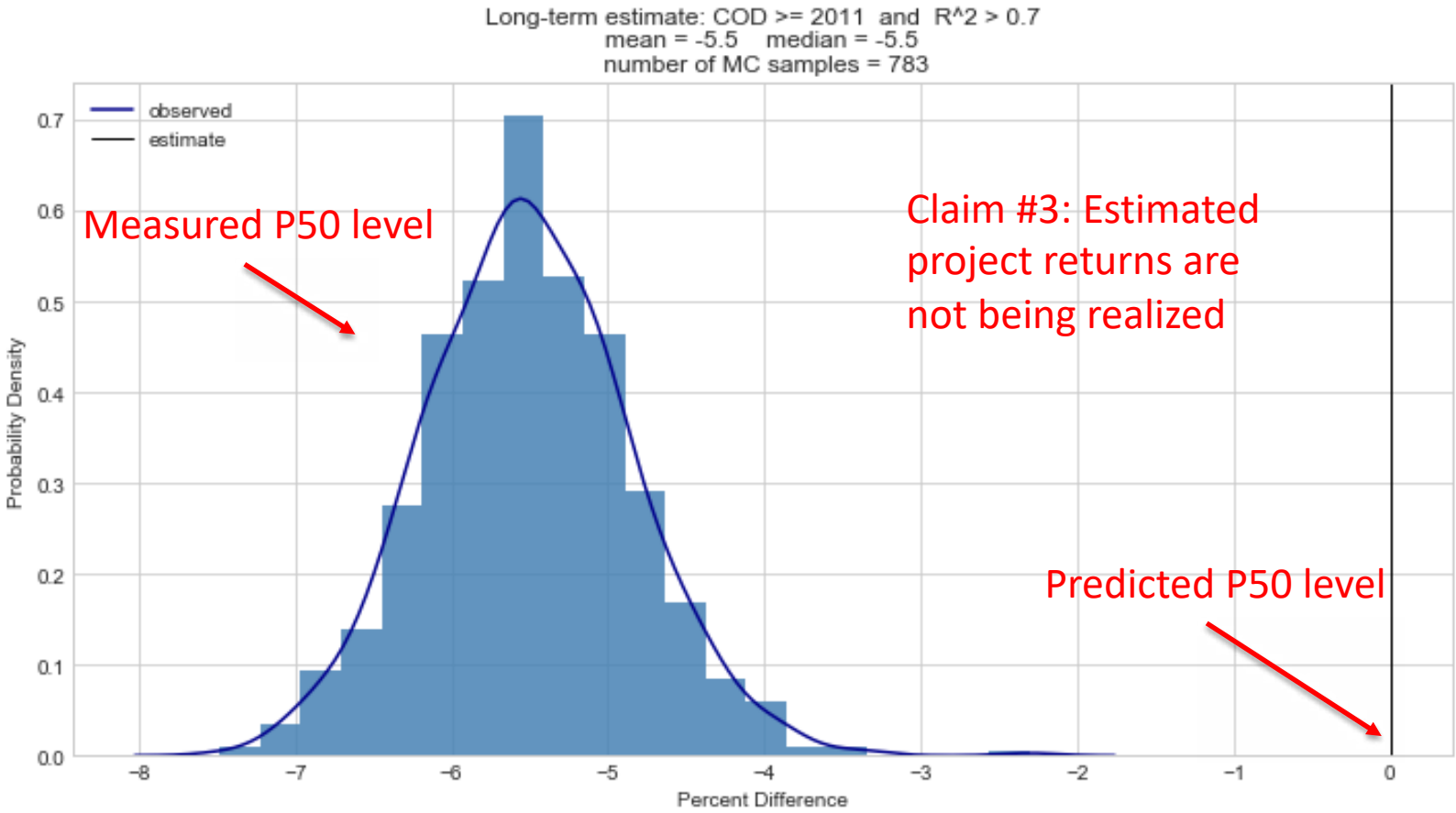
Istchenko, Rob; WSP; AWEA December 2014

WSP



Geer, Taylor; DNV GL; AWEA December 2014

Prediction Validation



Lunacek 2018
doi :10.1088/1742-6596/1037/6/062009

Prediction Validation

These predictions represent the state of the industry.

The industry needs better predictions.

The WP3 Benchmark Project is an industry-driven response to this reality.

Project Overview

Wind Plant Performance Prediction Benchmark (WP3) is a U.S. Department of Energy (DOE) funded project.

→ DOE Wind Power Program

→ Performance Risk, Uncertainty, and Finance (PRUF)

→ **WP3 Benchmark Project**

Project Overview

WP3 is industry collaboration.

- Compare preconstruction estimates to performance data
- 100+ projects, representing ~25GW of installed capacity
- First of its kind data sharing collaboration between gov't, owner/operators, consultants, independent engineers, and OEMs
- Improve methods for conducting preconstruction energy assessments using data from operating projects

Project Stakeholders

WP3 is unprecedented collaboration

- **Plant Owners**
  - ✓ EDF-RE, E-ON, Pattern, EDPR, RES, ENEL, Engie and Avangrid
- **Consultants**
  - ✓ ArcVera, DNV-GL, EAPC, EMD, Luminate, Mott Macdonald, K2 Management, Natural Power, UL ,WSP, Wood Group
- **OEMs**
  - ✓ Acciona, GE, Vestas, Nordex, Senvion, SGRE

Project Overview

Major Activities

- **Historical Validation Study**
  - Large scale study of Energy Yield Assessment accuracy
- **Benchmark at Scale**
  - Pilot Project: Trial run to fix the bugs
  - Phase 1: Disbursement and validation of first 10 projects

Historical Validation Study Results

Top-Down Analysis

Initial Results: Historical Validation Study (HVS)

Investigate underperformance in wind plant annual energy production using public/private data sources

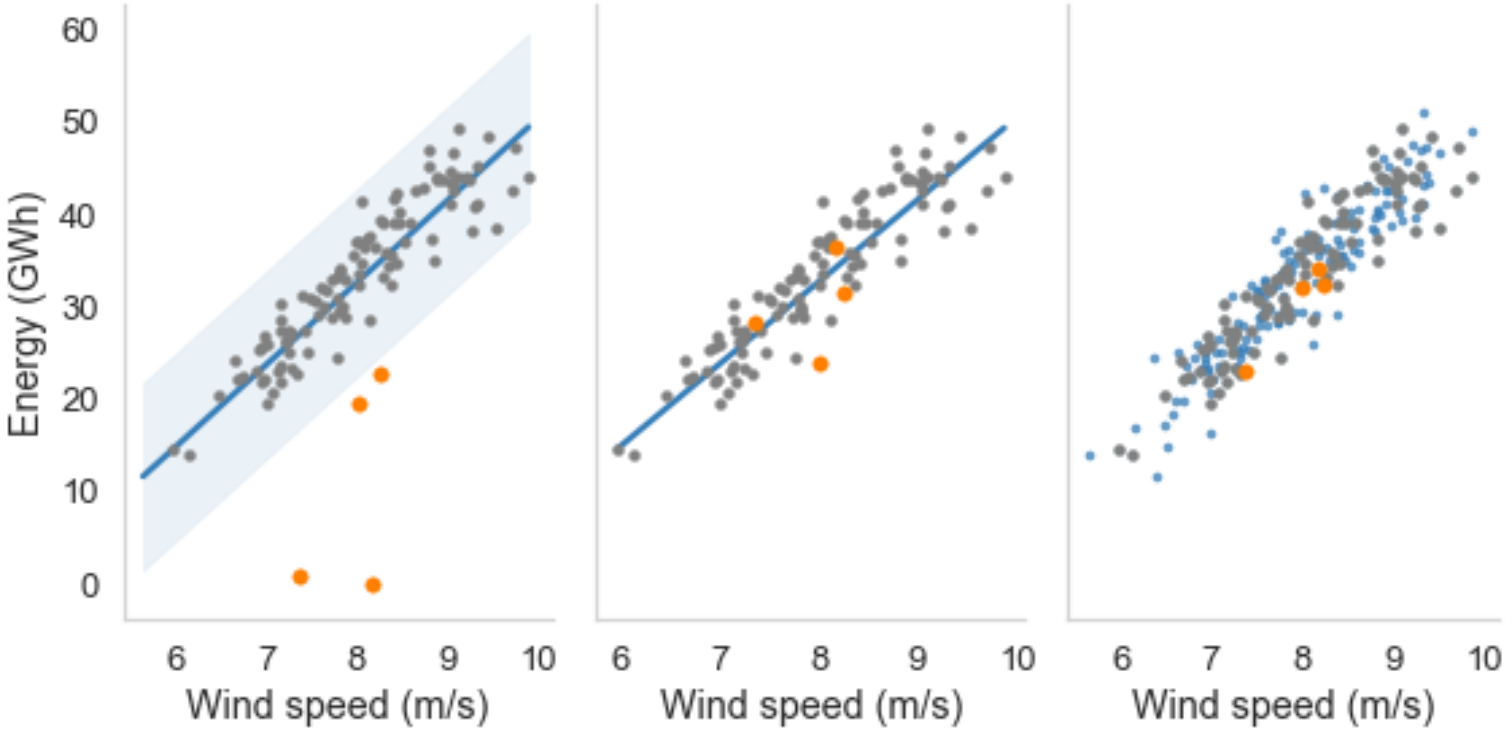
- Compares **preconstruction energy estimates** from industry partners to actual energy production data from **EIA**
  - *Initial analysis includes 62 projects*
- Analysis expected to reveal P50 bias, trends in wind farm characteristics (e.g., region/age/etc.)

Data Sources

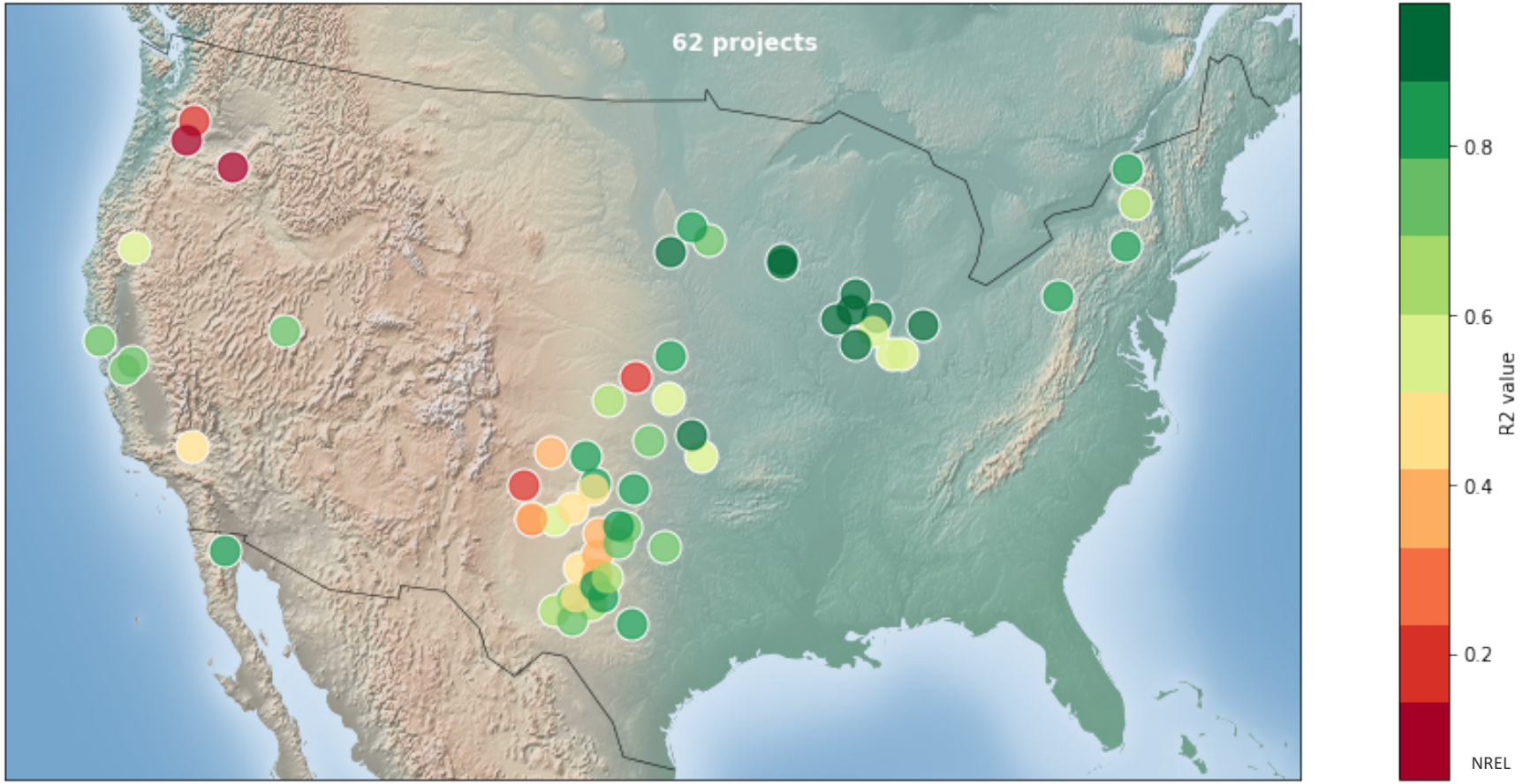
- **Preconstruction 3rd-party energy estimates**
  - Values reported by owners or gathered from consultant reports
- **Operational energy production data**
  - EIA data for monthly net energy production
- **Other data sources used for validation/correction**
  - SCADA data for validation of EIA data and outlier detection (monthly net energy, curtailment, and availability)
  - MERRA2 for atmospheric re-analysis (50m monthly wind speed averages and long-term climatology
- **Currently limited to 62 projects**
  - Exploring options for expanding by troubleshooting EIA data issues

Raw Data and Outlier Detection

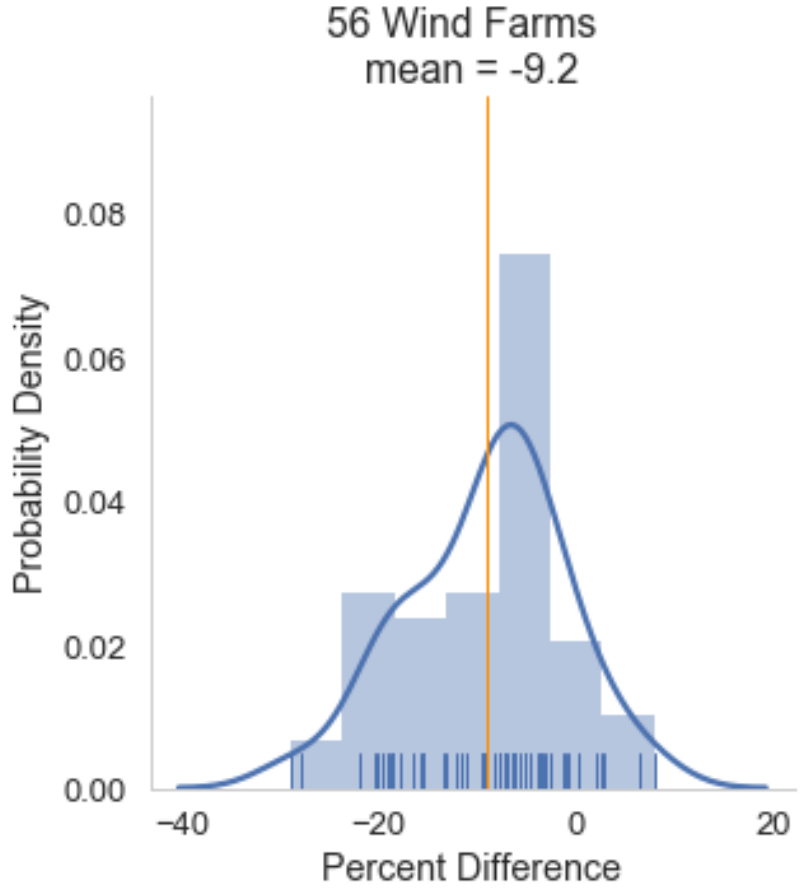
May not be accurate → *corrected*.
Small number of years → windiness corrected

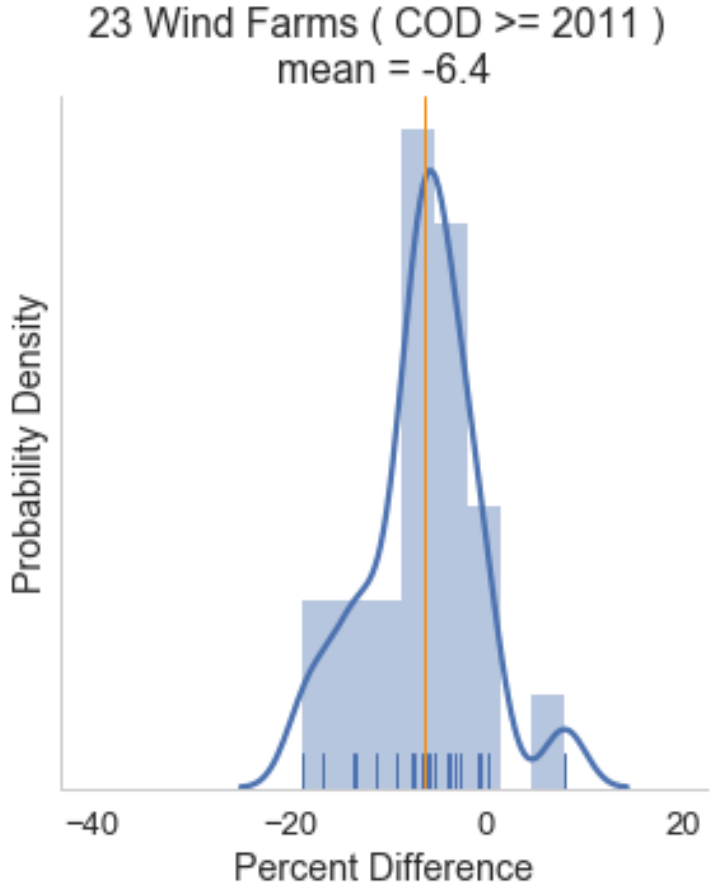


Linear Model Fit

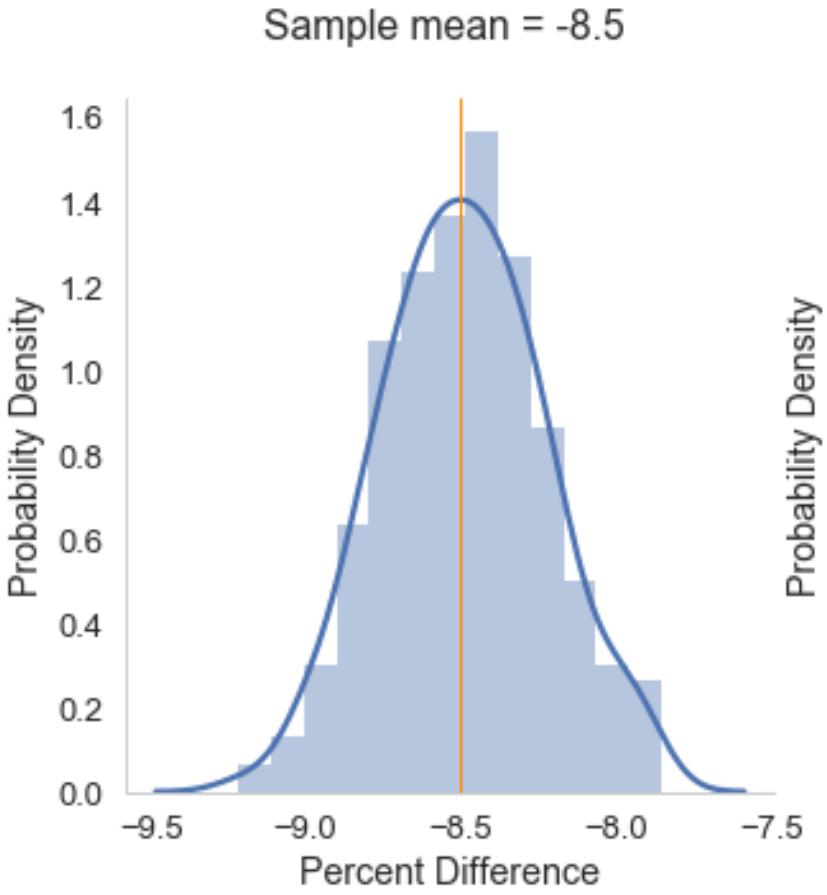


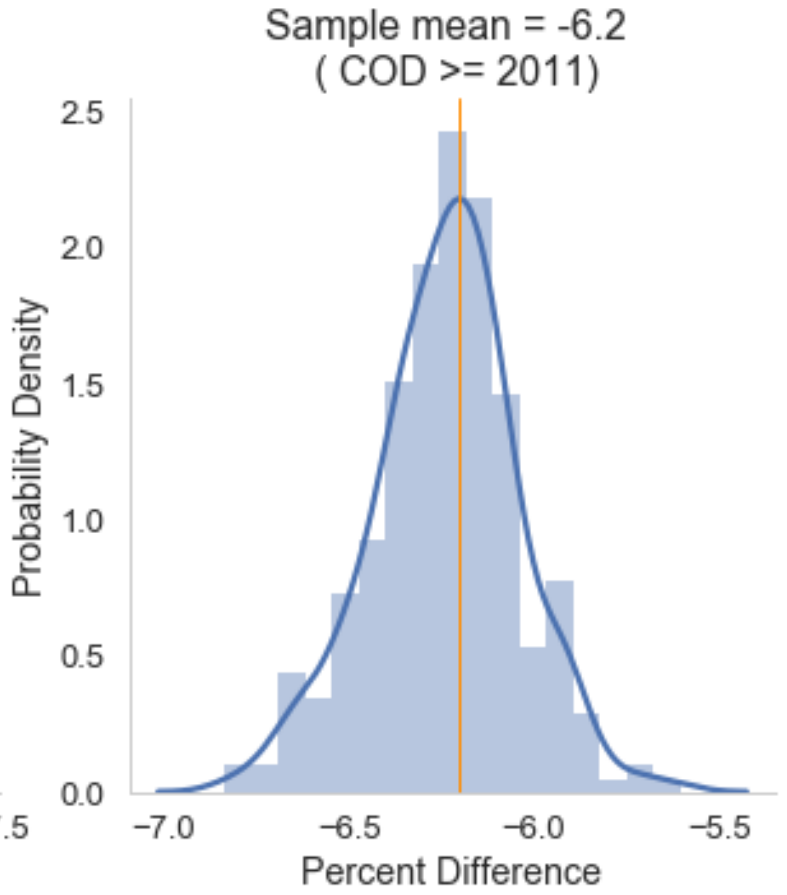
Results: Raw


56 Wind Farms
mean = -9.2
Probability Density
0.08
0.06
0.04
0.02
0.00
−40
−20
0
20
Percent Difference

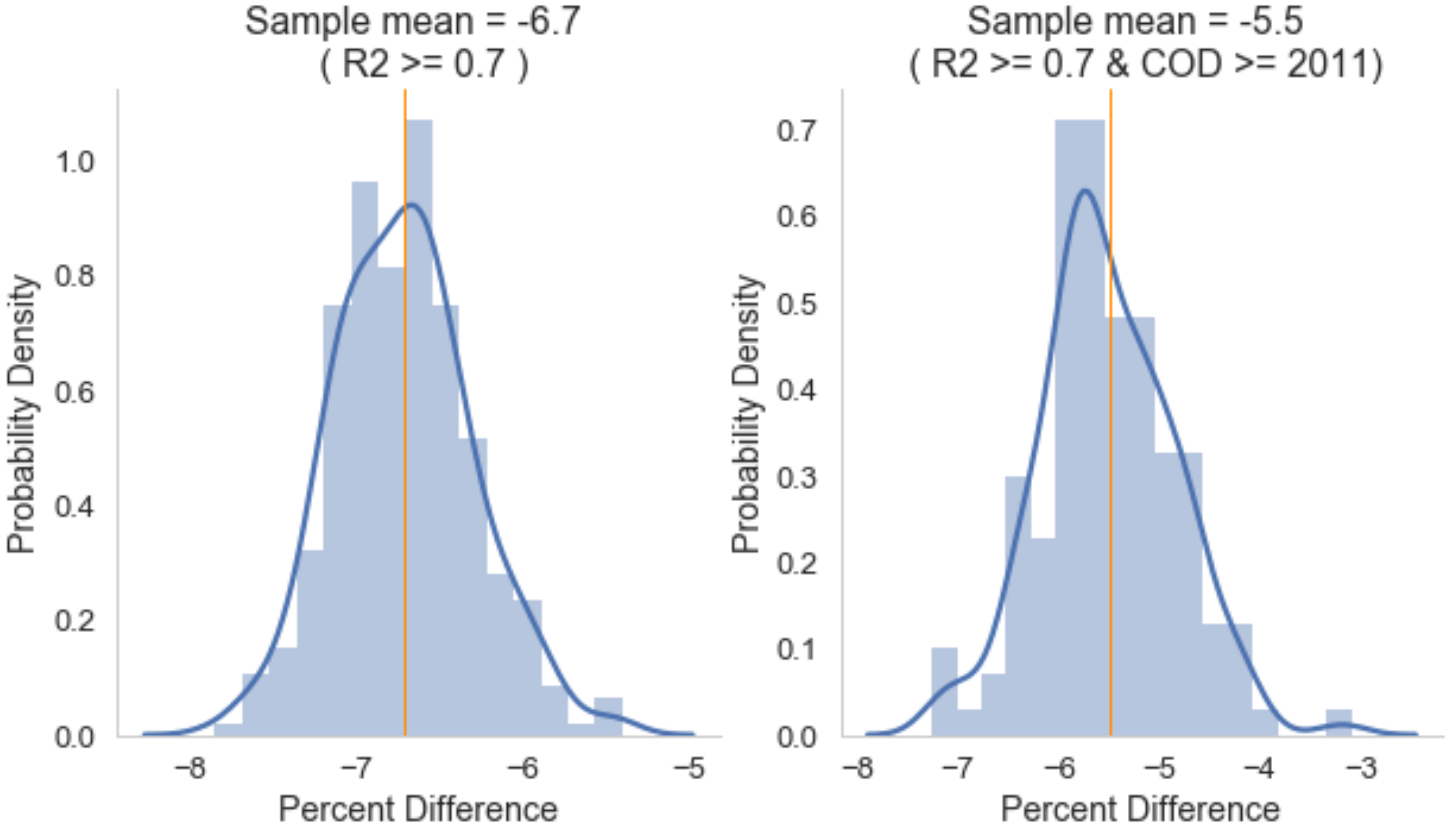

23 Wind Farms (COD >= 2011)
mean = -6.4
Probability Density
−40
−20
0
20
Percent Difference

Results: Outlier Corrected





Results: Windiness



Results in average HVS bias of ~**3.5-4.5% for "modern" projects**

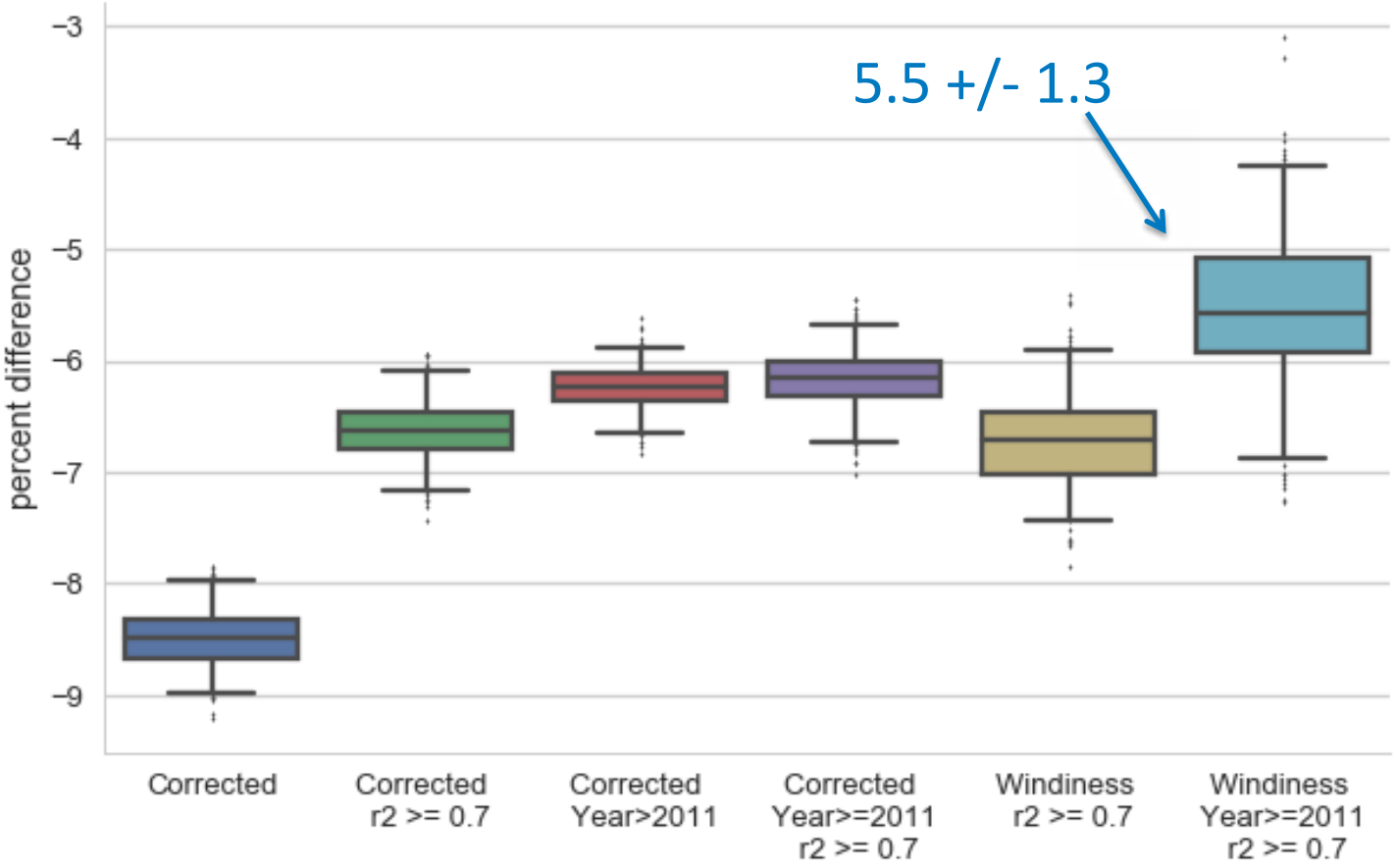
Sapling Assumptions for Uncertainty Modeling

- Remove first year: [***True***, False]
- Minimum duration:[***12***, 24 months]
- Wind data:
  [MERRA2 50m, ***MERRA2 80m***, ERA-I]
- Corrected noise: [0, 2]
- Windiness noise: [0, 2]
- ***Bootstrap linear model***
- Upper bound: ***[2, 4]***
- Lower bound: ***[2, 4]***

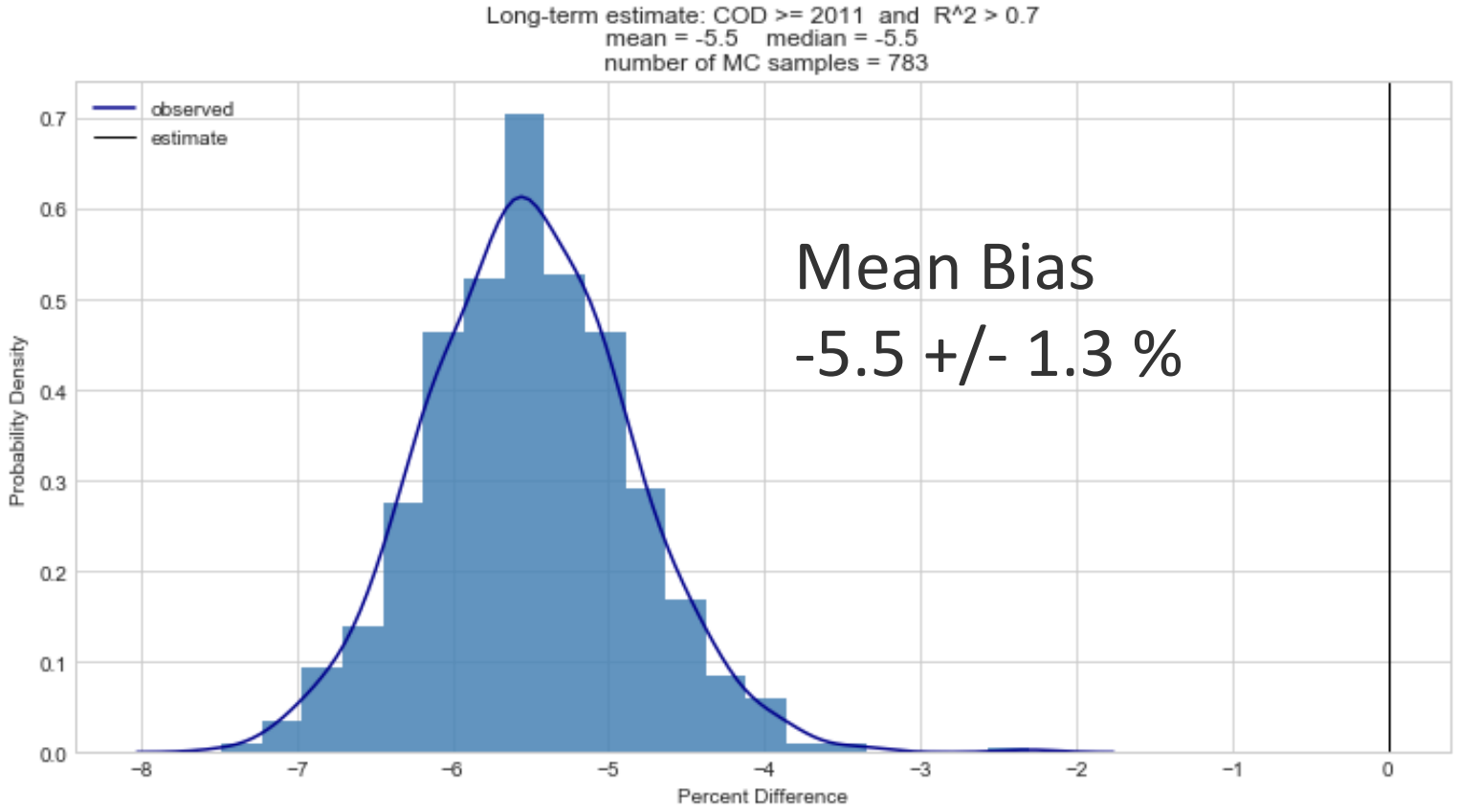
Sampled large space to quantify uncertainty (10K samples).

Big Picture of Bias

Results in average HVS bias of **~3.5-4.5% for "modern" projects when corrected for curtailment**

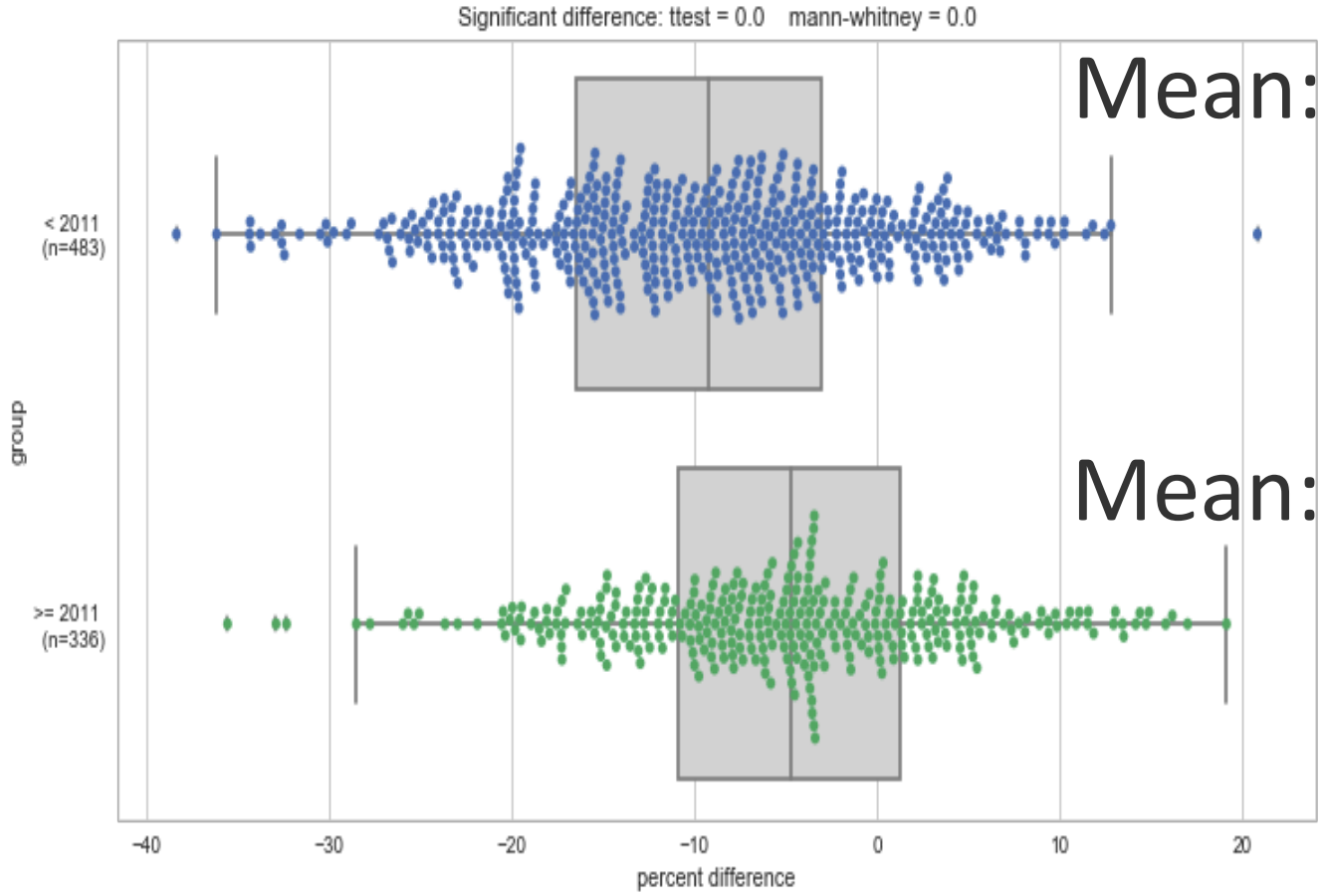


Big Picture of Bias



Results in average HVS bias of **~3.5-4.5% for "modern" projects** when correcting for curtailment

Evidence of improvement



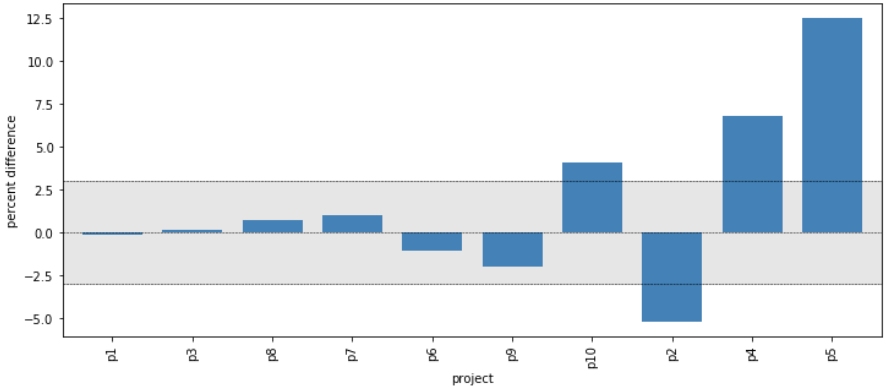
Benchmark at Scale

Bottom-Up Analysis

Benchmark Work Activities

Pilot Project

- 10 consultants participated
- Lessons learned for scaling WP3



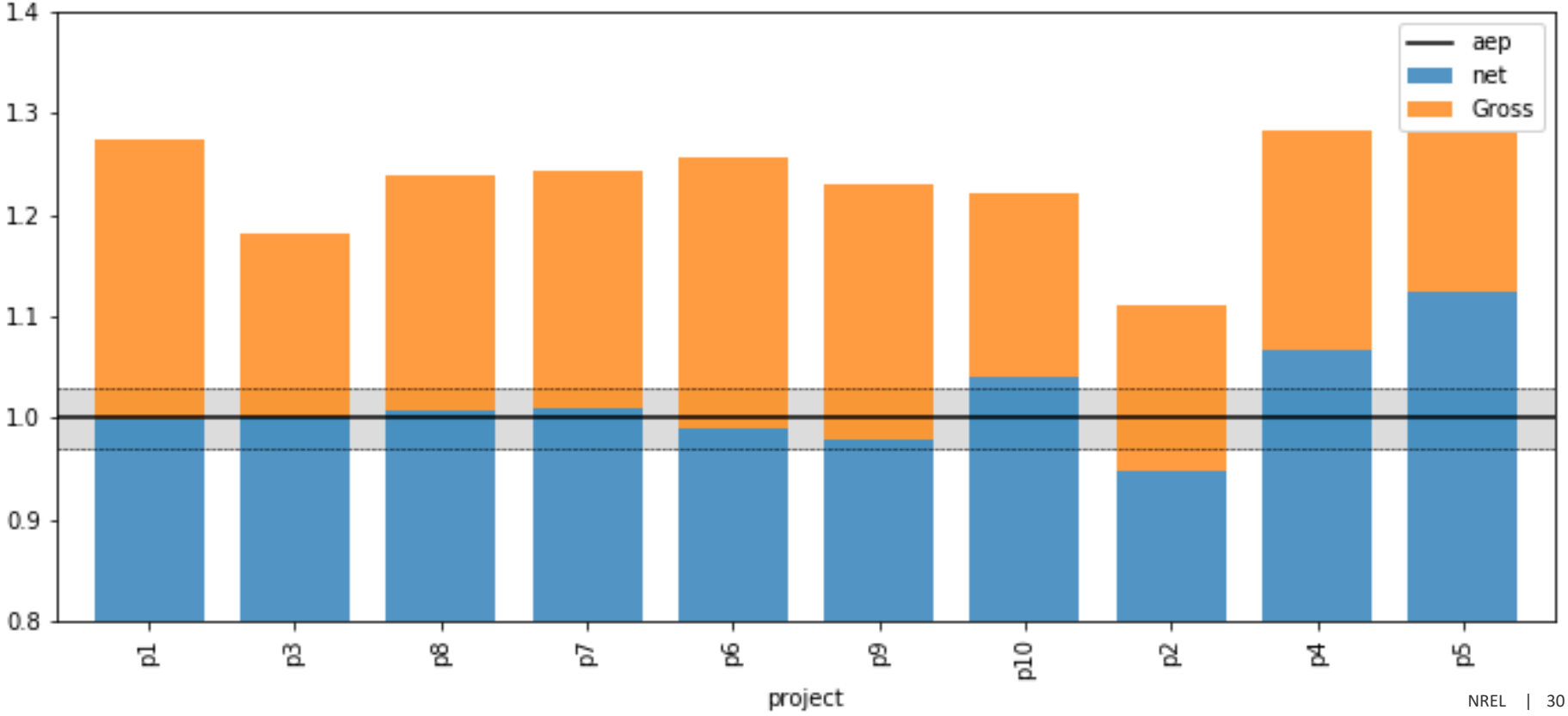
Phase 1: (First 10 projects)

- Broader technology and geography representation
- Expected Results: Sept. 2019

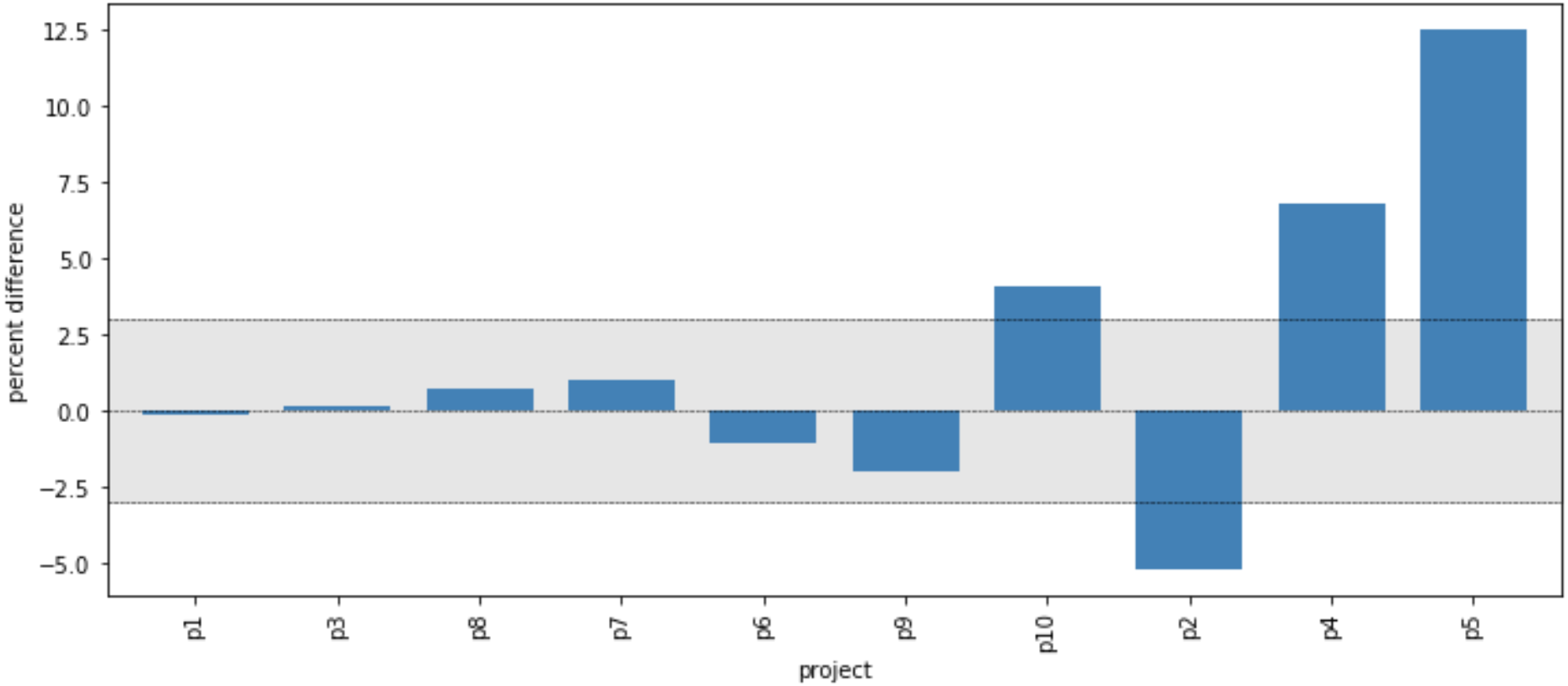
Level 1

Net, Gross, and Uncertainty

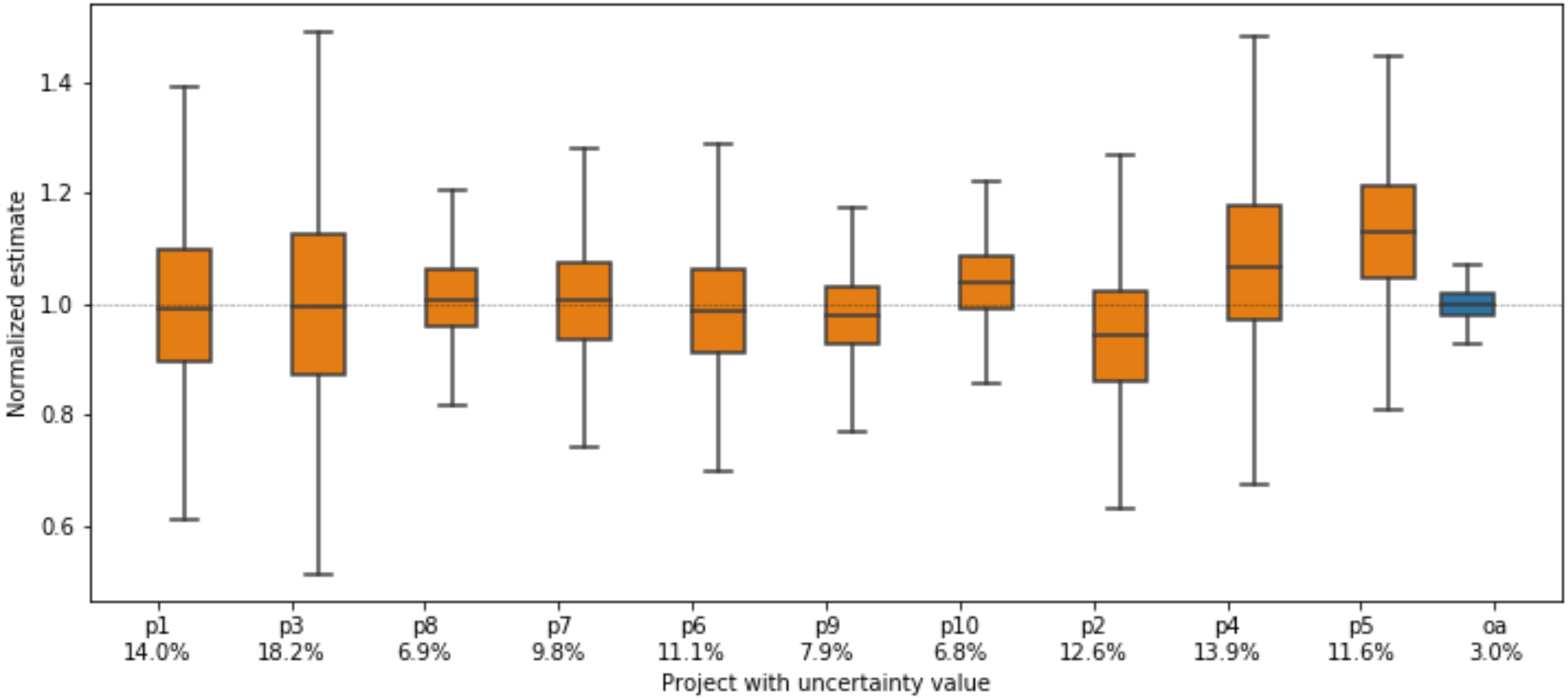
Normalized AEP vs. Net



P50 vs. OA Percent Difference



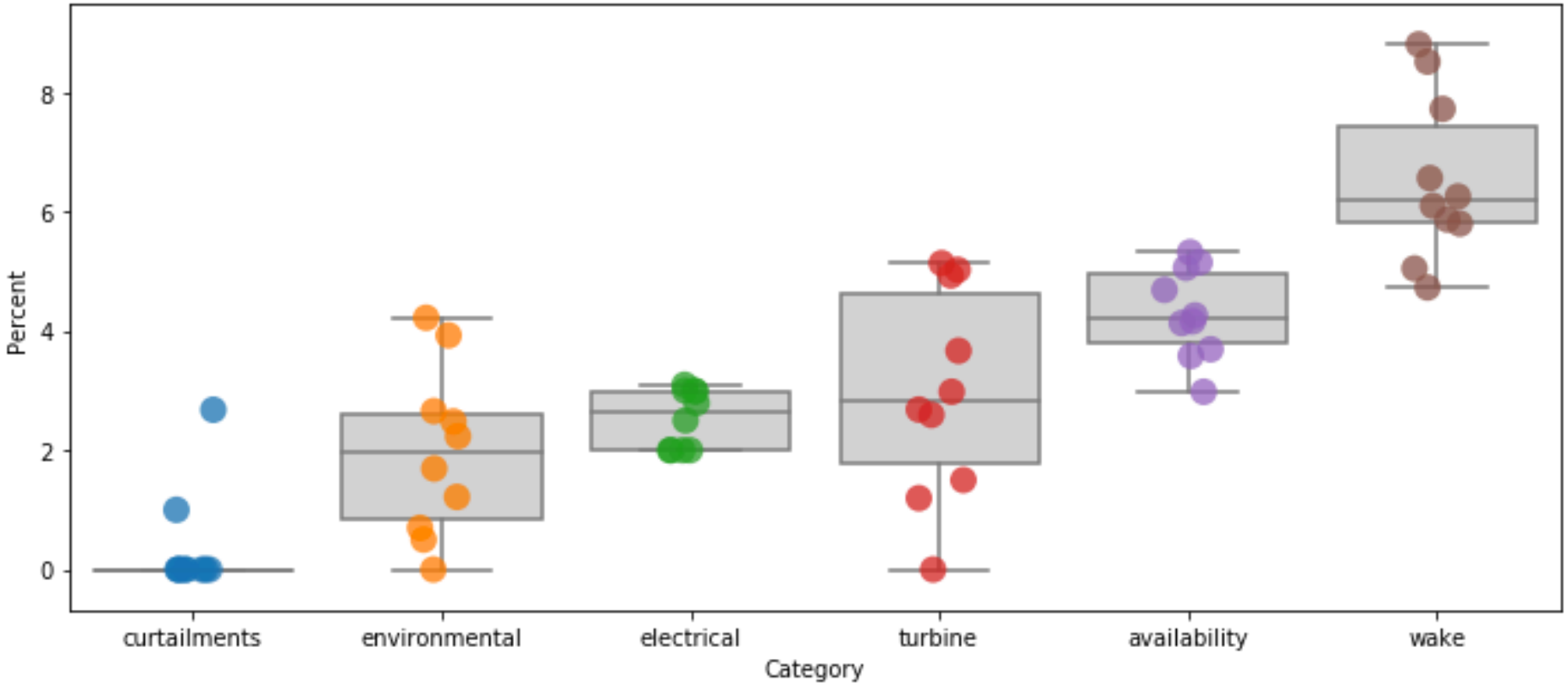
Uncertainty (10 yr 1 STD)



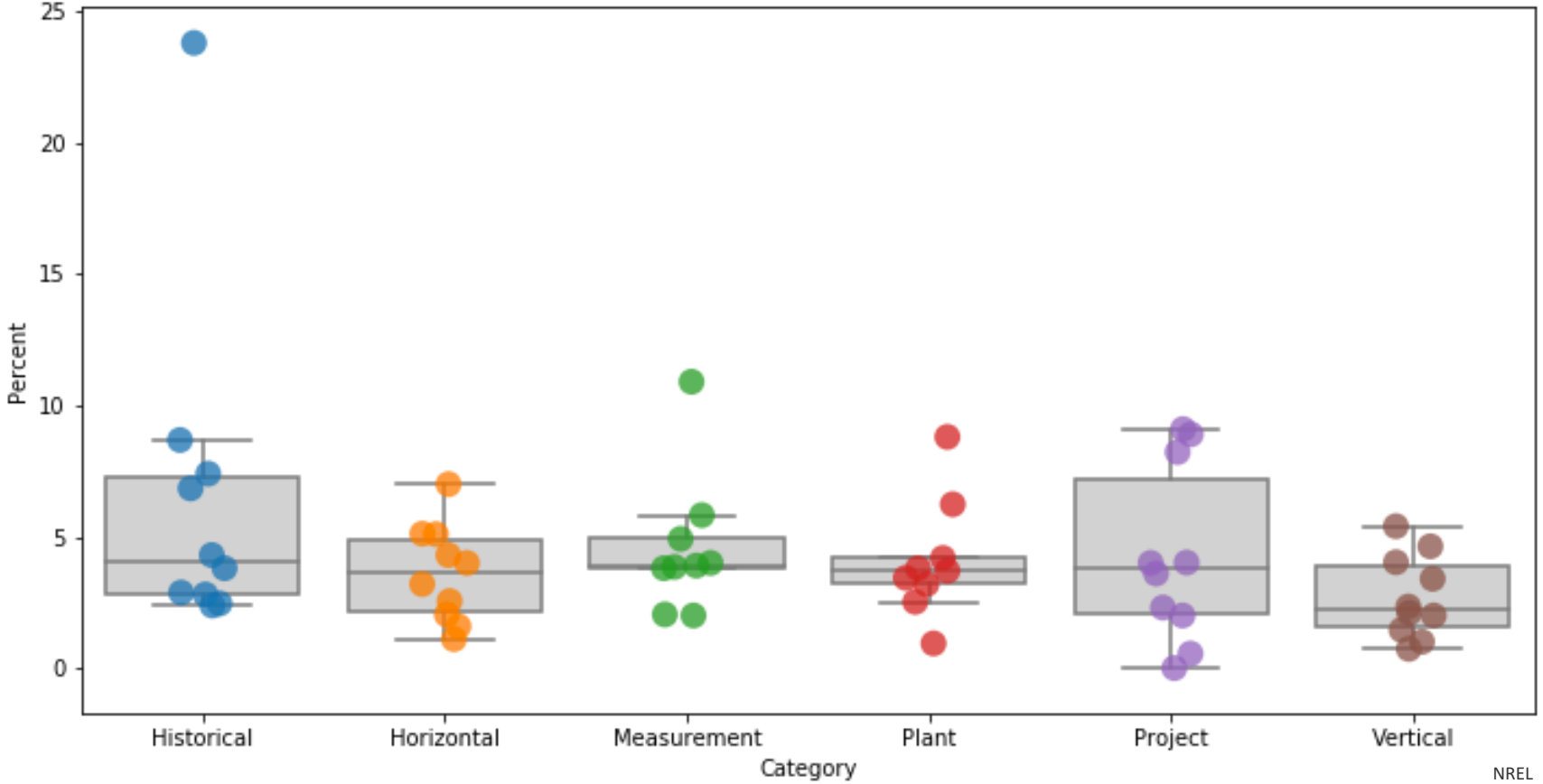
Level 2

Energy Yield, Loss, and Uncertainty Categories

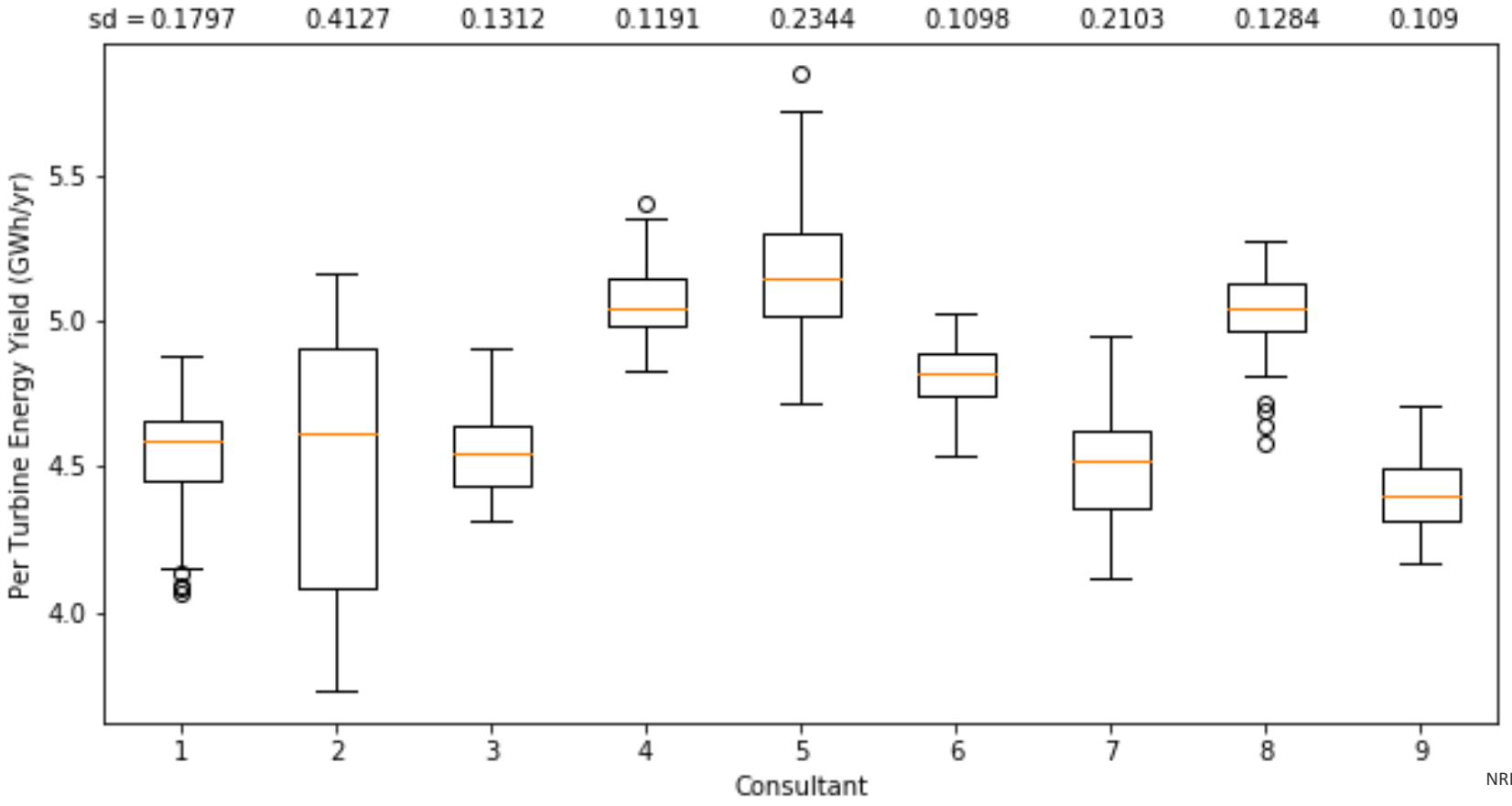
Energy Losses



Uncertainty



Energy Yield per Turbine (*energy quartiles*)

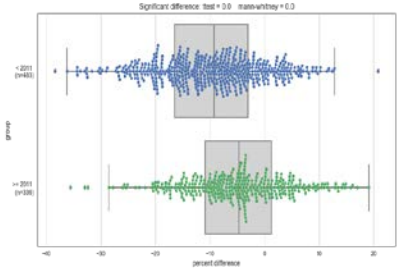


Conclusions

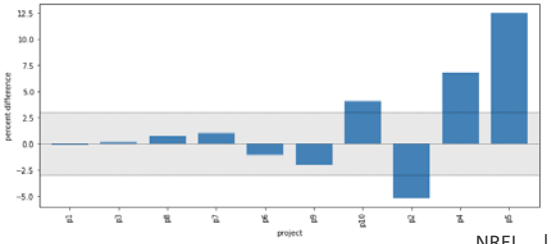
Conclusions

Data sharing at scale is hard but not impossible

HVS results demonstrate bias AND improvement



Benchmark:
Right for the wrong reasons?



Next Steps

Benchmark Phase 1 Results out Fall 2019

Benchmark Phase 2 starting now.
Get engaged!

Thank you!

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https://a2e.energy.gov/projects/wp3

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